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THE CONSTANT-HEAD-ORIFICE FARM TURNOUT

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CONTENTS

The Constant-Head-Orifice Farm Turnout[1]

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ABSTRACT

The constant-head-orifice turnout, a structure used for the control and measurement of irrigation water, was calibrated and evaluated in the laboratory. The effects on discharge of sediment, high canal velocities, varying downstream water levels and plugging of the orifice gate by debris were studied.

The structure provided reasonably accurate measurement of discharge under most operating conditions. However, when the gate opening was obstructed with debris or when the tail water level was increased, discharges were much less than indicated by the calibration curve. For large discharges, the staff gages furnished erratic indications of the differential head on the orifice gate.

INTRODUCTION

The constant-head-orifice farm turnout (CHO) is a structure designed to perform the dual functions of measuring and controlling irrigation water. It is normally used to divert water from canals to smaller farm laterals. The CHO was developed by the U.S. Bureau of Reclamation (USBR); variations of the device are in use on many USBR projects.

This paper reports a study of the operating characteristics of constant-head-orifice farm turnouts in use on the Riverton, Wyoming, irrigation project. Design drawings for the turnouts in use on this project[2] indicate geometries slightly different than for the turnouts calibrated in the USBR laboratories.[3] However, the same discharge rating is currently being used for both sets of structures.

Some water users on the Riverton project were doubtful of the water measurement accuracy of the Riverton turnouts. This study was undertaken to determine if measurement inaccuracies exist, and if so, if they are caused by use of the incorrect discharge table for

1 Contribution from Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Colorado Agricultural Experiment Station, Fort Collins, Colo. This research project was supported in part with funds made available from Region IV, U.S. Bureau of Reclamation, Billings, Mont.

2 U.S. Bureau of Reclamation. Design drawing for Wyoming canal lateral system--farm turnout--18-inch constant-head-orifice. Riverton Project Plan No. 12P-339, 36-D-1642. 1950 (revised).

3 U.S. Bureau of Reclamation. Calibration of the constant-head-orifice turnout. Engin. and Geol. Control and Res. Div. Lab. Rpt. 216. Denver, Colo. 1946.

the structure or by adverse operating conditions in the field. Full scale models of the Riverton constant-head-orifice farm turnouts were calibrated and the calibrations compared with the discharge tables furnished by the USBR.[4] Deviations from the calibration were then determined for various adverse operating conditions such as sediment or trash in the structure, varying tail water depths, and varying velocities in the supply canal.

Modular steel panels have been recently marketed by commercial firms for use in irrigation structures. A constant-head-orifice turnout constructed of such panels would be lower in cost than a reinforced concrete turnout. The steel structure could also be dismantled and moved from one place to another on a farm as irrigation development changes. Design and calibration information for such a steel constant-head-orifice turnout is included toward the end of this report.

EQUIPMENT AND PROCEDURE

A CHO field installation is shown in figure 1. The orifice gate, located at the upstream end of the turnout, is used for flow measurement and control. Calibration curves for these turnouts are drawn in terms of discharge as a function of height of orifice-gate opening for a constant differential head of 0.20 foot across the orifice gate. The turnout gate, located at the downstream end is used to establish and maintain the constant differential head ($\Delta \underline{h}$) on the orifice gate. The water surface upstream from the orifice gate is assumed to remain at a constant level during operation.

Figure 1.--Field installation of constant-head-orifice farm turnout. The orifice gate is in the center of the photograph and the turnout gate at the upper left. Flow is from right to left.

The Riverton CHO, with a 24-inch-wide orifice gate, was evaluated in both indoor and outdoor test channels. For the indoor tests, the structure was constructed to full scale and placed in a 4-foot-wide flume. The approach flow was in line with the center line of the CHO. An orifice that had been recently calibrated by means of a volumetric tank was mounted on the pipeline supplying water to the flume, thus allowing accurate measurement of discharge through the structure.

Four geometries of the CHO were calibrated in the indoor tests. The first (figures 2 and 3) had the CHO floor level with the floor of the approach channel. The second was similar to the first except for the presence of a 5-inch-thick wall behind the orifice gate. The dimensions of this wall are indicated by dashed lines in the plan view in figure 2. The third, featuring a steeply sloping approach to the CHO, is shown in figures 4 and 5. The fourth, featuring an approach with an abrupt dropoff, was formed by removing the steeply sloping approach to the CHO. It is indicated by the dashed line in figure 4.

As a part of the indoor tests, the effects of adverse operating conditions on water measurement errors were determined. Sediment deposits were placed in the structure to determine the effects on the discharge coefficient. Also, weeds were placed in the orifice-gate opening to determine the magnitude of reduction of discharge that might be caused by this type of debris.

The test structures were equipped with staff gages and with piezometers connected to stilling wells to measure the differential head on the orifice gate. The staff gages were located as indicated in figures 2 and 4. Piezometers were placed on the wall opposite the staff gages, 12 inches above the bottom of the gate opening.

[4] See footnote 3.

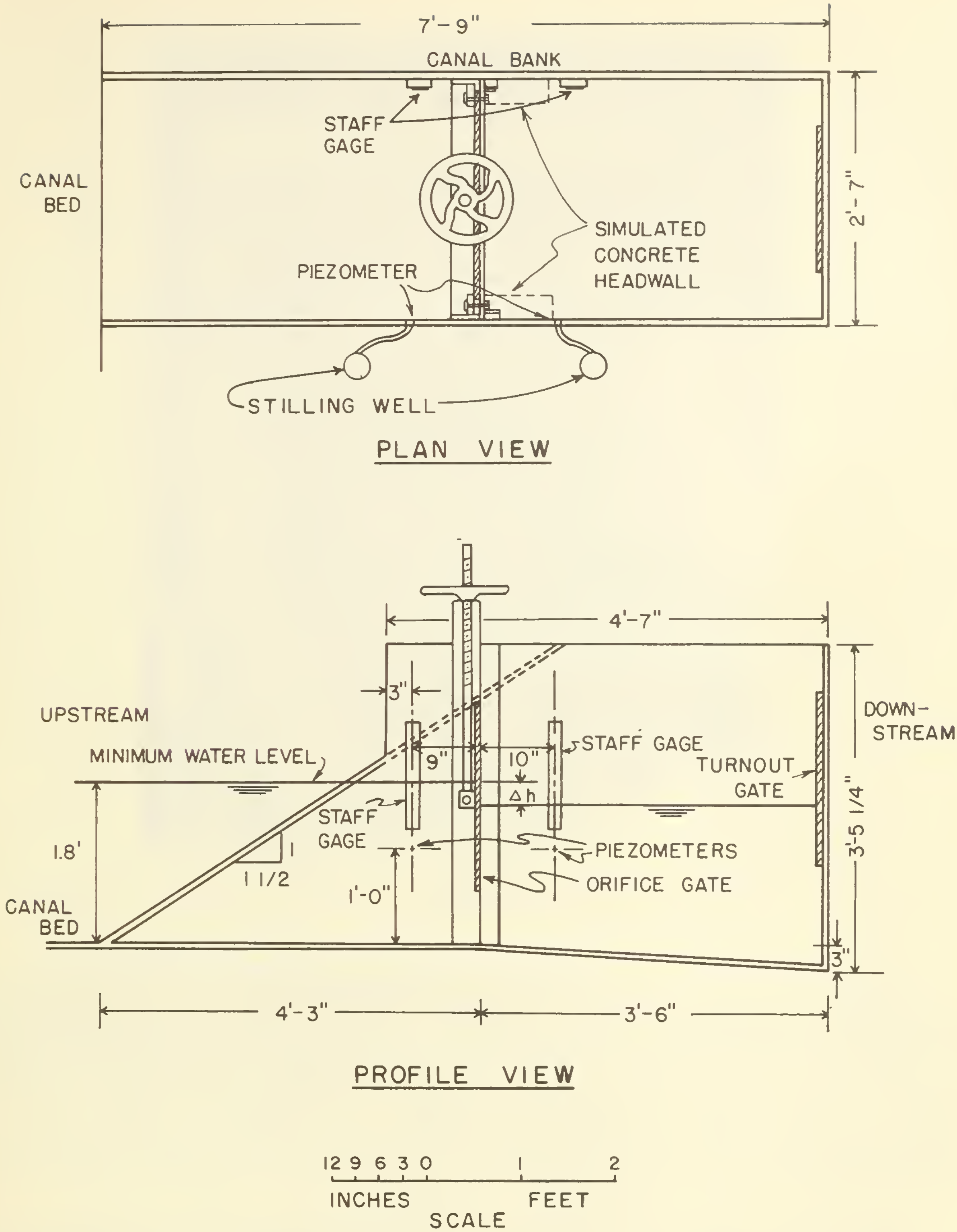

Figure 2.--Line drawings of Riverton constant-head-orifice turnout with horizontal approach.

Figure 3.--Riverton constant-head-orifice turnout with horizontal approach in indoor test channel.

The outdoor studies of the CHO were conducted at the Bellvue test facility near Fort Collins, Colo. where water could be diverted from the Cache La Poudre River to provide high flow rates. A trapezoidal canal section was simulated with the CHO at right angles to it. The geometry of a field installation was thus duplicated exactly at the CHO entrance. The amount of flow bypassing the CHO entrance was regulated by a tailgate at the end of the canal section. The same CHO was installed in the outdoor laboratory as was used in the indoor tests, but with only the horizontal and steeply sloping approaches (figs. 6 and 7). Discharge through the CHO was measured with an 8-inch trapezoidal measuring flume placed downstream from the structure. Staff gages and piezometers were placed in exactly the same locations as for the indoor studies.

In addition to the effects on discharge of placing the orifice gate at right angles to flow in the canal, the effects of the following two special operating conditions were evaluated in the outdoor studies: (1) the variation of discharge coefficient with velocity in the canal, and (2) the variation in discharge with tail water level.

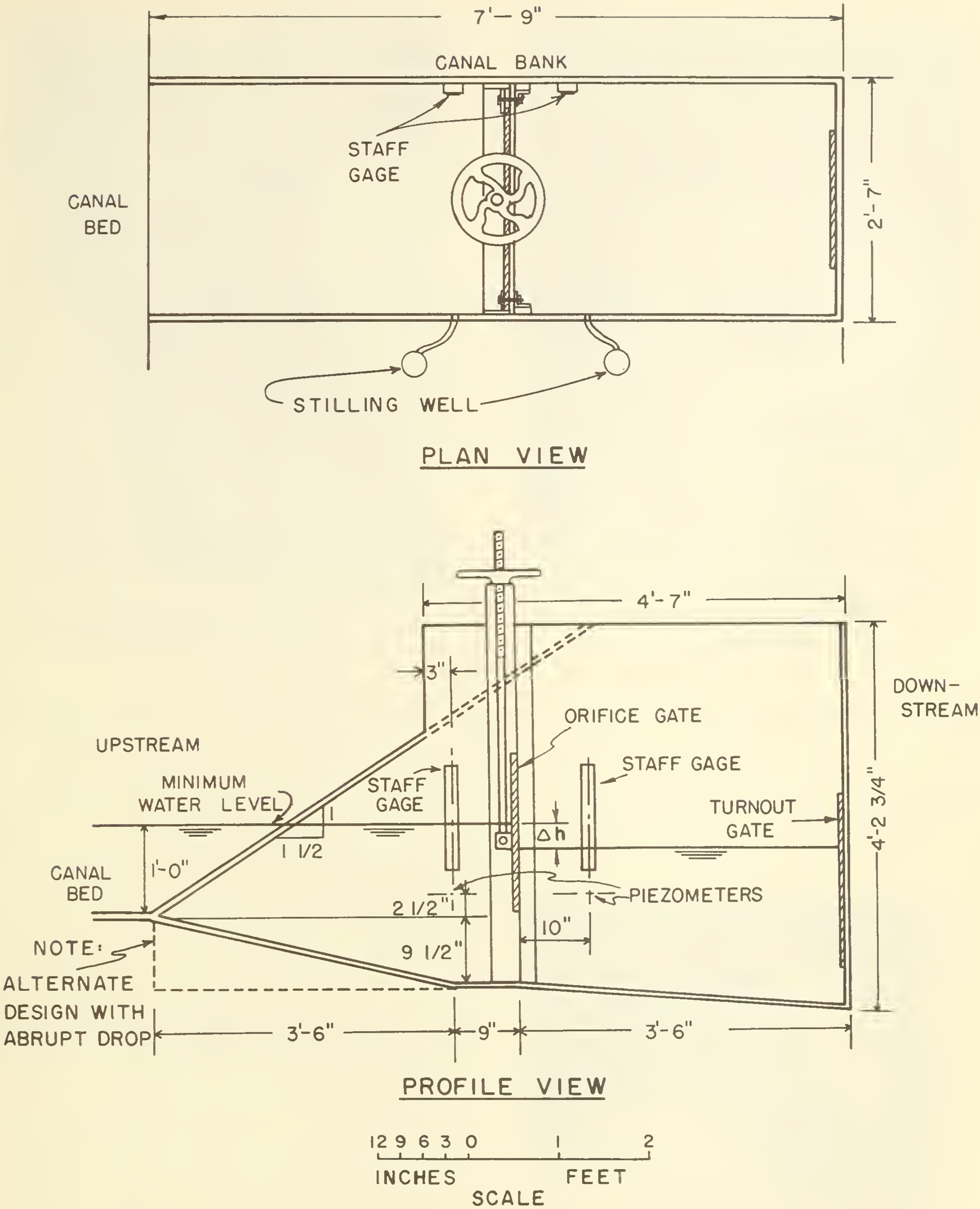

Figure 4.--Line drawings of Riverton constant-head-orifice turnout with steeply sloping approach.

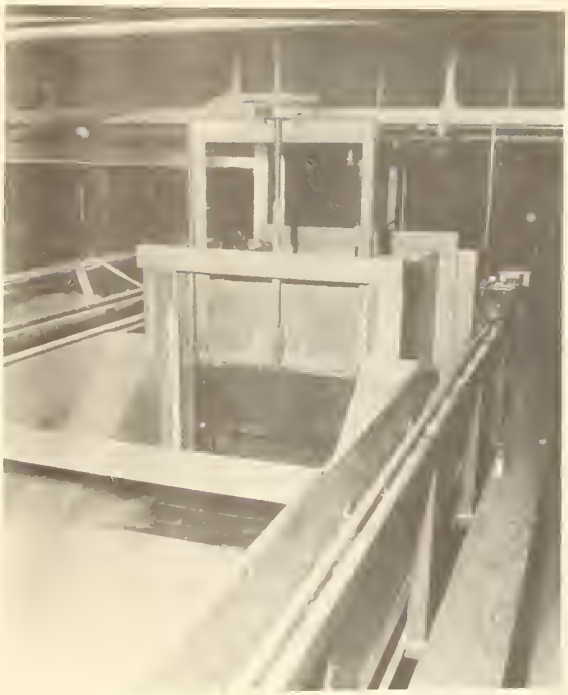

Figure 5.--Riverton constant-head-orifice turnout with steeply sloping approach in indoor test channel.

Figure 6.--Riverton constant-head-orifice turnout with horizontal approach in outdoor test channel.

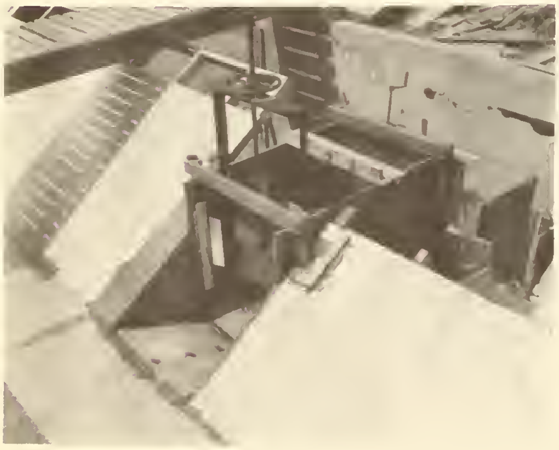

Figure 7.--Riverton constant-head-orifice turnout with steeply sloping approach in outdoor test channel.

RESULTS

Calibration Curves

The discharge of the constant head orifices of 24-inch width was determined for the full range of orifice gate opening--0 to 1.0 foot. Dimensions of the gate openings were measured accurately and differential heads were adjusted to approximately 0.20 foot. Observed discharges were corrected by the ratio $\sqrt{0.20 \text{ ft.}/\Delta h_{\text{observed}}}$ to determine the discharge at a differential head equal to exactly 0.20 foot.

Horizontal Approach

The calibration curve for the Riverton CHO with a horizontal approach is shown in figure 8. Solid data points represent the indoor tests; open data points represent the outdoor tests. The dashed line is the standard calibration curve for CHO's used by the USBR. Data points taken indoors fall within plus or minus 4 percent of the standard curve. The indoor data were recorded with the upstream water level in the range specified on the design drawings for the structure (that is, 1.8 to 2.1 feet above the seat of the orifice gate). A mean line drawn through the outdoor data shows a maximum of 6-percent deviation from the standard calibration. Water depths in the canal for outdoor tests on the horizontal approach condition ranged from 1.46 to 1.67 feet.

Headwall Modification

The CHO with a horizontal approach was varied slightly for a few supplemental tests to conform with structures rated by the USBR. The variation consisted of placing a 5-inch-thick headwall immediately downstream from the orifice gate. The results of the modification, presented in figure 9, show that the calibration curve is very similar to that obtained

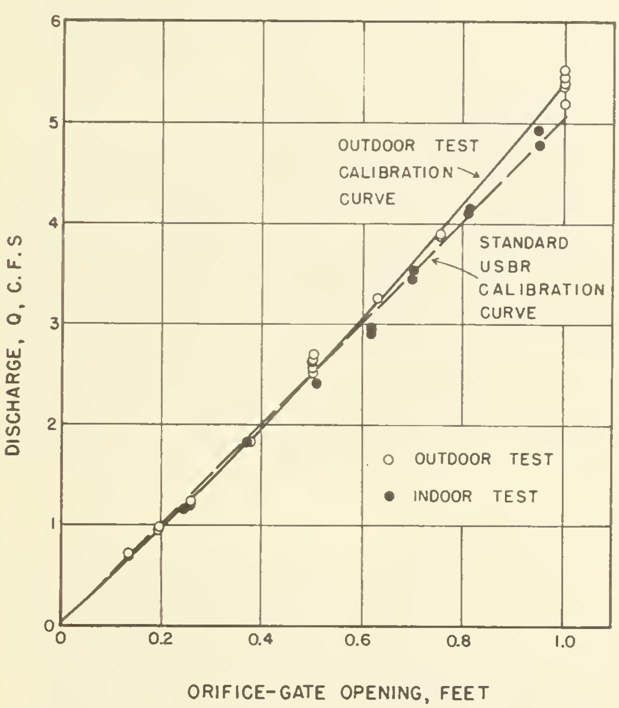

Figure 8.--Calibration curve for constant-head-orifice turnout with horizontal approach.

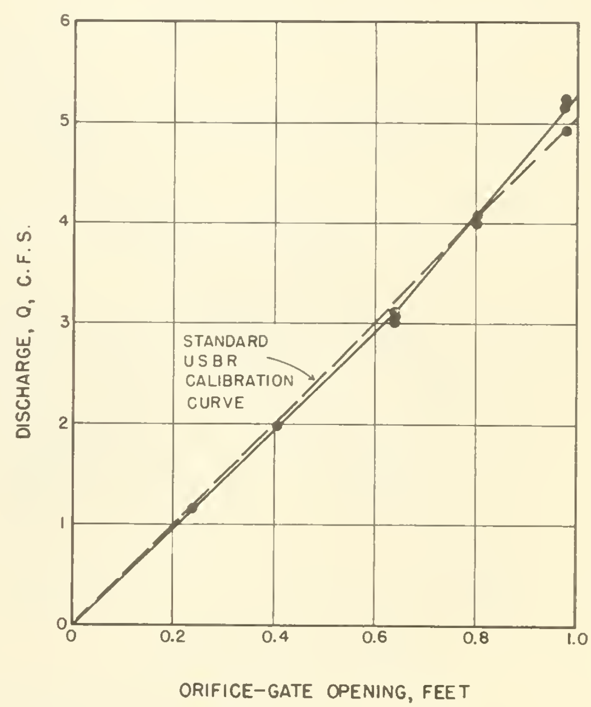

Figure 9.--Calibration curve for constant-head-orifice turnout with 5-inch headwall behind orifice gate--horizontal approach, indoor tests.

in the first series of tests. Maximum deviation between these data and the USBR discharge table was 5 percent and occurred at the largest discharges.

Steep Approach

The constant-head-orifice turnout was further altered to provide a steep approach to the orifice gate, corresponding to the steepest approach shown in the Riverton design drawings. Data for this condition again indicate close agreement with the USBR standard discharge table up to discharges of about 4 c.f.s. (fig. 10). The two curves then begin to diverge and finally, at the highest discharge for which the structure is intended, 5 c.f.s., a 7-percent deviation occurred for the indoor tests. Extreme scatter in the experimental data appeared at large orifice-gate openings for the outdoor tests.

The structures rated by the USBR did not include any with the steeply sloping approach section. The presence of the steep approach increases the velocity of approach to the orifice. A higher approach velocity tends to increase the effective head on the orifice gate and may account for the data from the current tests showing higher discharges than USBR calibration curves. For orifice-gate openings less than 0.9 foot, the measured discharges were within plus or minus 5 percent of the USBR standard discharge table.

Rather poor flow conditions occurred throughout the structure with the steep approach. The jet passing through the orifice gate struck the downstream wall of the basin between the orifice and turnout gates and was deflected upward, causing boils in the two downstream corners. As a result, a very choppy water surface existed throughout this basin (fig. 11). Water surface fluctuations on the downstream staff gage were as great as 0.1 foot, making it difficult to obtain accurate readings. A stilling device was developed which could be placed in front of the staff gage to provide for a more stable water surface. The stilling device, a basin, is shown in use in figure 12. The dimensions and position of this stilling basin, as well as those of an anti-vortex baffle to facilitate reading the upstream staff gage, are shown in figure 13. The stilling basin can be easily constructed. It can be placed in existing constant head orifices or carried by the ditch rider from one structure to the next when measurements are being taken.

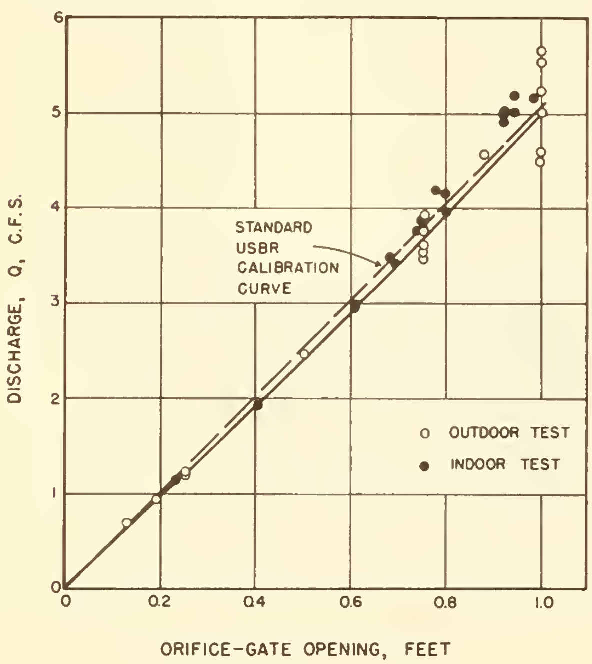

Figure 10.--Calibration curves for constant-head-orifice turnout with steeply sloping approach.

Poor flow conditions also existed on the upstream side of the orifice gate for the structure with steep approach flow. Large vortices occurred on both sides of the channel immediately upstream from the gate, one of them in front of the upstream staff gage. This vortex caused a reduction in the water level at the upstream gage, giving a small error in gage reading. No alteration of the structure was found that would provide consistently accurate readings at this gage. To assure accurate head readings at this location, a piezometer and stilling well should be provided.

Abrupt Approach

When the sloping upstream approach was removed, an abrupt dropoff was formed upstream from the orifice gate. This dropoff occurred 36.75 inches upstream from the gate and had a height of 9.5 inches. CHO's with a similar abrupt drop are currently in use in some USBR projects in Nebraska. Since this

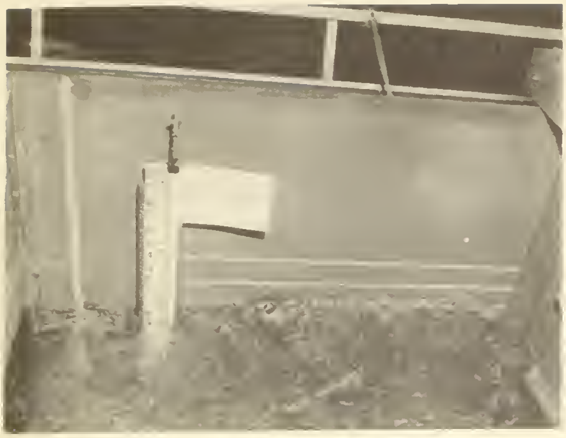

Figure 11.--Water surface disturbance in basin between orifice and turnout gates.

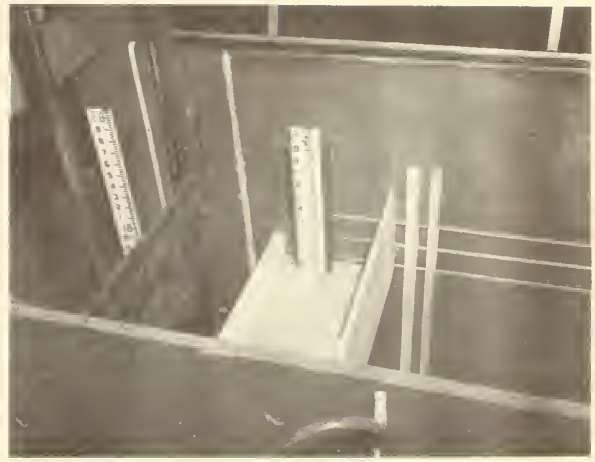

Figure 12.--Stilling basin device for improving ease and accuracy of reading downstream staff gage.

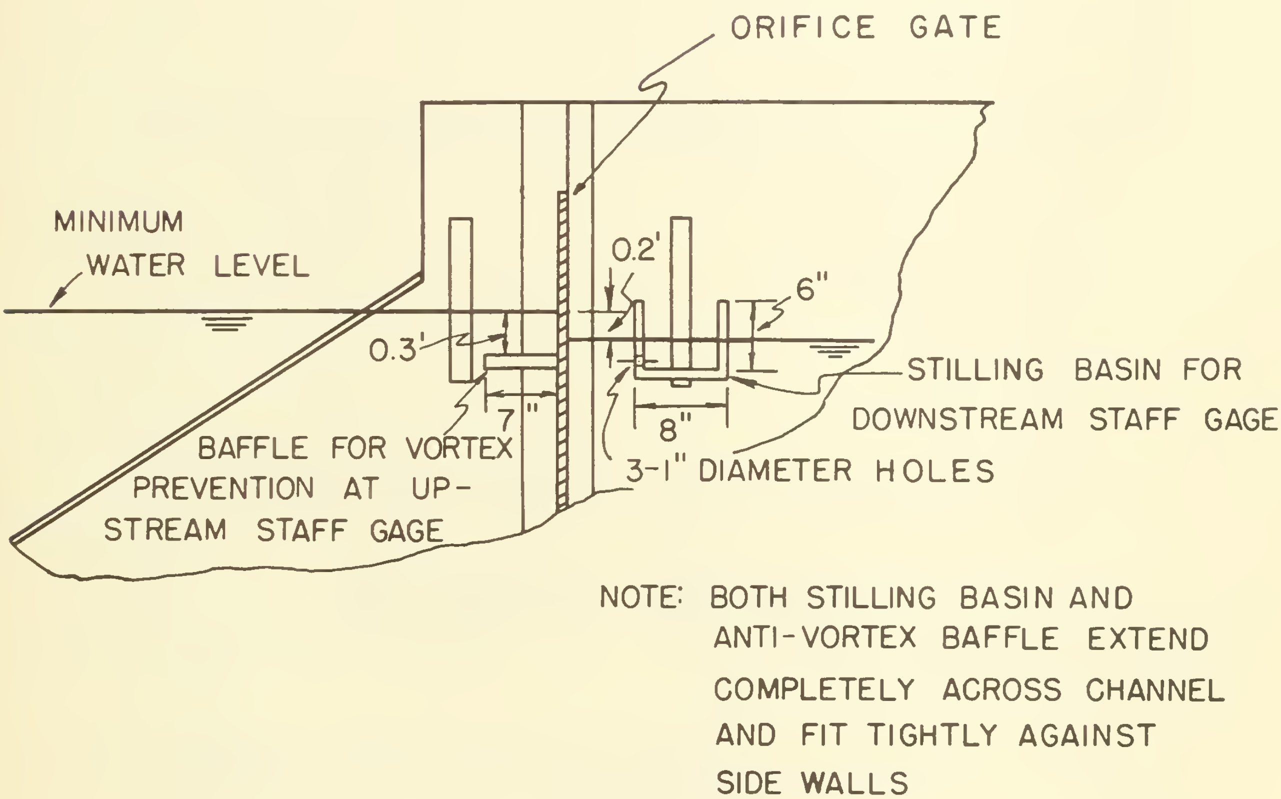

Figure 13.--Devices to reduce water level fluctuations at staff gages.

modification of the structure was readily made, a small number of data points were taken in hope that they might be useful in evaluation of the structure. Data for this condition, shown in figure 14, correspond very closely to the USBR standard discharge table, even at high discharges.

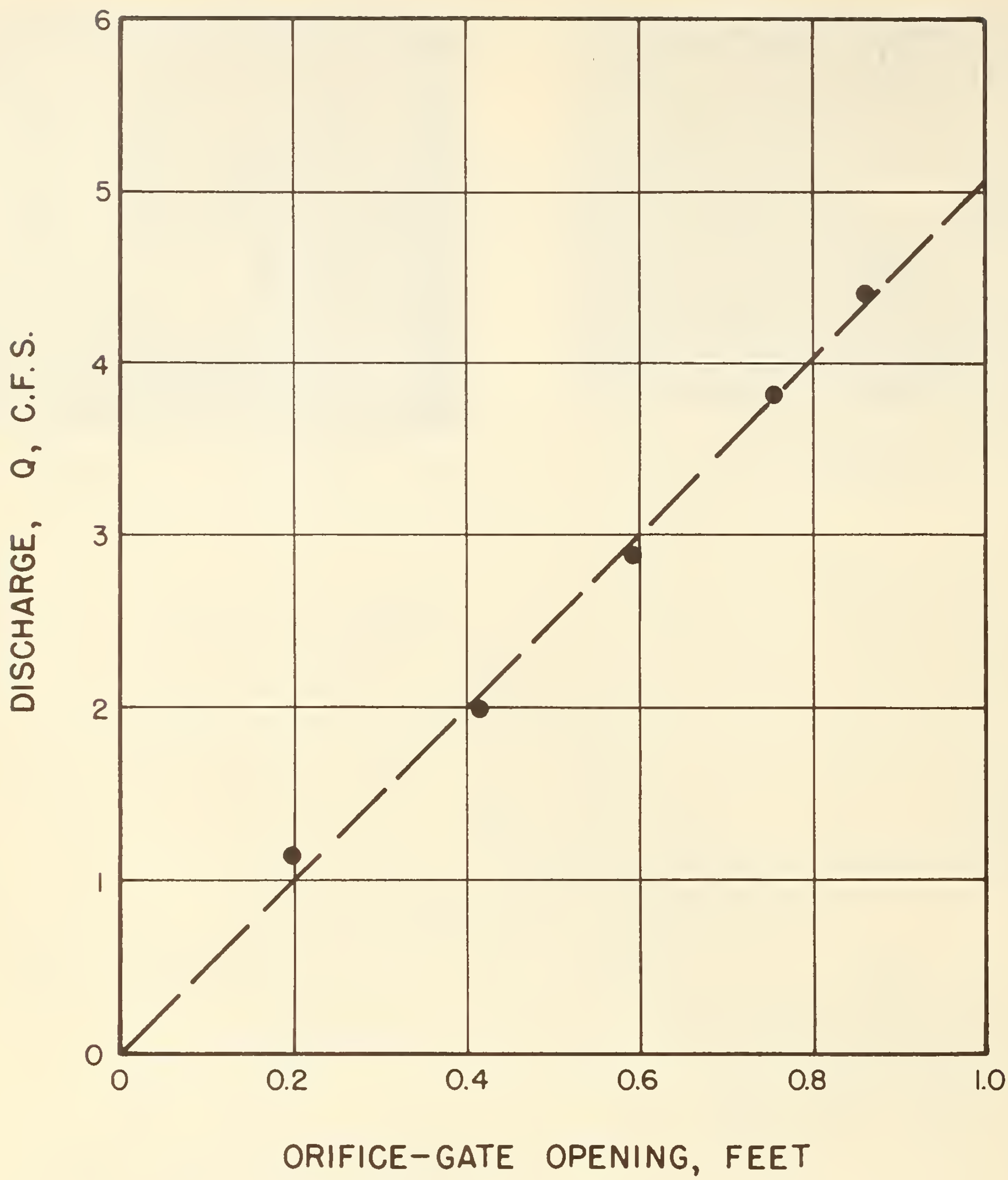

Figure 14.--Calibration curve for constant-head-orifice turnout with abrupt drop upstream from orifice gate, indoor tests.

Discharge Coefficients

The geometry of the flow pattern in the CHO would be expected to affect the discharge coefficient, $\underline{C_d}$. A dimensionless variable describing the geometry is $\underline{d}/\underline{a}$ where $\underline{d}$ is the depth of water upstream from the orifice gate, and $\underline{a}$ represents the height of the orifice gate opening. The variation of discharge coefficient with the ratio $\underline{d}/\underline{a}$ is shown in figures 15 to 18. Figures 15 and 16 present data for the CHO with horizontal approach and figures 17 and 18 present data for the steep approach. In all cases, the discharge coefficient remains approximately constant at 0.65 for large values of $\underline{d}/\underline{a}$. As $\underline{d}/\underline{a}$ decreases below 4.0

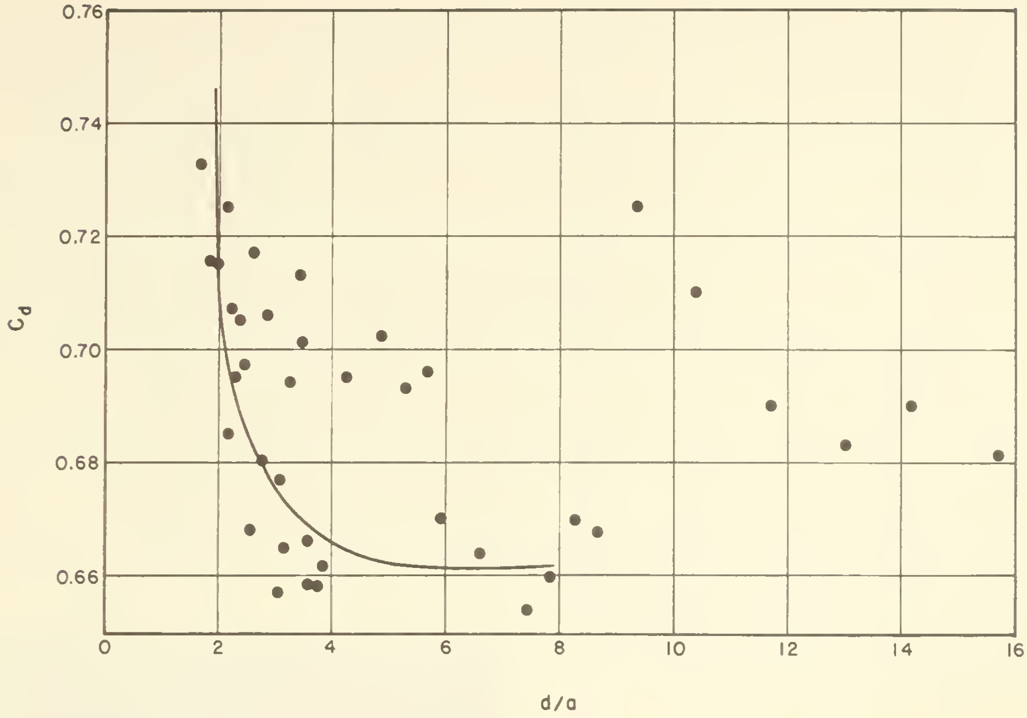

Figure 15.--Variation of discharge coefficients with flow pattern geometry for constant-head-orifice turnout with horizontal approach, indoor tests.

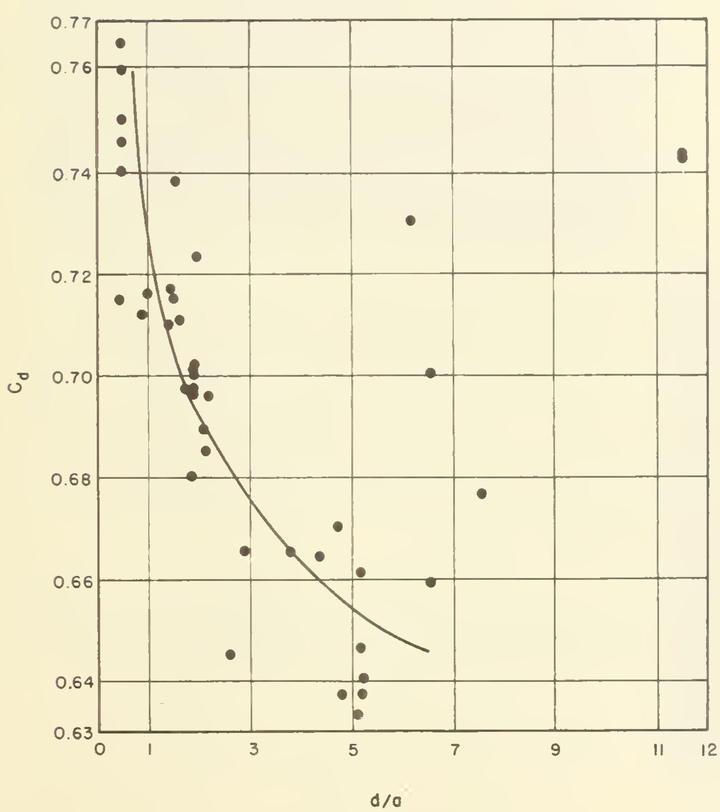

Figure 16.--Variation of discharge coefficient with flow pattern geometry for constant-head-orifice turnout with horizontal approach, outdoor tests.

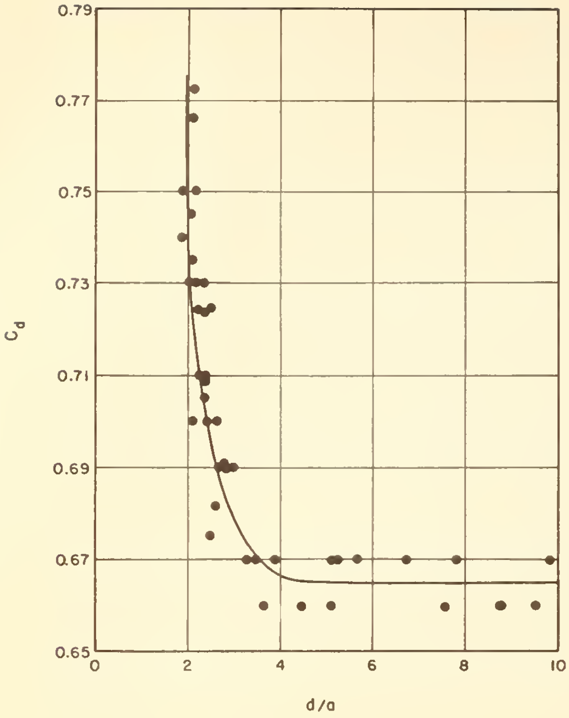

Figure 17.--Variation of discharge coefficient with flow pattern geometry for constant-head-orifice turnout with steeply sloping approach, indoor tests.

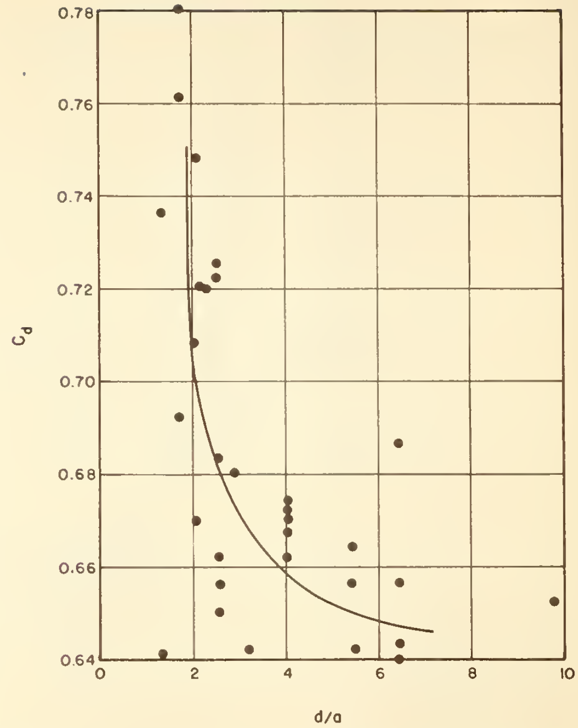

Figure 18.--Variation of discharge coefficient with flow pattern geometry for constant-head-orifice turnout with steeply sloping approach, outdoor tests.

the discharge coefficient increases rapidly. The specified minimum upstream water depths in the Riverton design drawings are such that $\underline{d}/\underline{a}$ values will always be large enough so that $\underline{C}_{\underline{d}}$ will remain nearly constant.

Weeds

In field operation of the constant-head-orifice turnout, sediment-laden water may make it difficult for the ditch rider to determine that the orifice gate is unobstructed and completely open to flow. A very likely source of gate-plugging is weeds that have become waterlogged and have lodged in the gate opening. Once a few weeds have become lodged, smaller trash particles can be filtered out of the flow and the gate can ultimately become completely plugged. In order to determine the possible reduction in flow from such an occurrence, several tests were made wherein weeds were stuffed into the gate opening. These tests were conducted indoors with the steep approach to the orifice gate. The discharge was adjusted to give the standard differential head, and the percentage reduction in discharge from that with an unplugged gate opening was determined. The amount of plugging of the gate cannot be quantitatively described, but a rough description of the test conditions and results is given in table 1 and shown by photographs in figure 19.

Four tests indicated that a plugged gate opening could easily cause reductions of 40 percent or more in discharge below that for the same unobstructed gate opening. It is essential that the gate opening be kept free of weeds and debris if the structure is to measure and regulate flow accurately.

Table 1.--Effect of orifice-gate plugging on discharge

Orifice gate opening	Description of test conditions	Reduction in discharge
Foot		Percent
0.259	Three Kochia weeds placed loosely in orifice-gate opening.	12.3
.259	Two Kochia weeds placed tightly in orifice-gate opening.	44.6
.80	Three Kochia weeds placed tightly in orifice-gate opening.	30.6
.80	Three Kochia weeds placed very tightly in orifice-gate opening.	46.0

Figure 19.--Test conditions for study of flow reduction due to weeds plugging orifice gate.

Sediment Deposits

When the constant-head-orifice turnout is used to divert water from unlined ditches, sediment being carried in these ditches may also be diverted and may be deposited in various parts of the CHO. A medium sand was introduced into the laboratory test channel to see if deposits of this nature caused any effect on the discharge rating of the orifice. The sediment was placed by hand in the approach section of the CHO. The flow of water, which reaches high velocities through the orifice and turnout gates, carried part of the sediment through the structure and into the downstream channel. The sand deposits remaining after all sediment motion had ceased are shown in figures 20a and 20b. It is apparent from the data in figure 21, that the sediment remaining in the approach to the structure caused no change in discharge compared to that shown by the standard USBR calibration curve (calibration without sediment). It can be assumed that the constant-head-orifice turnout has sufficient self-cleaning properties to prevent sediment deposits from affecting the discharge measurement.

Figure 20.--Typical sediment deposits on (a) horizontal and (b) steeply sloping approach floors.

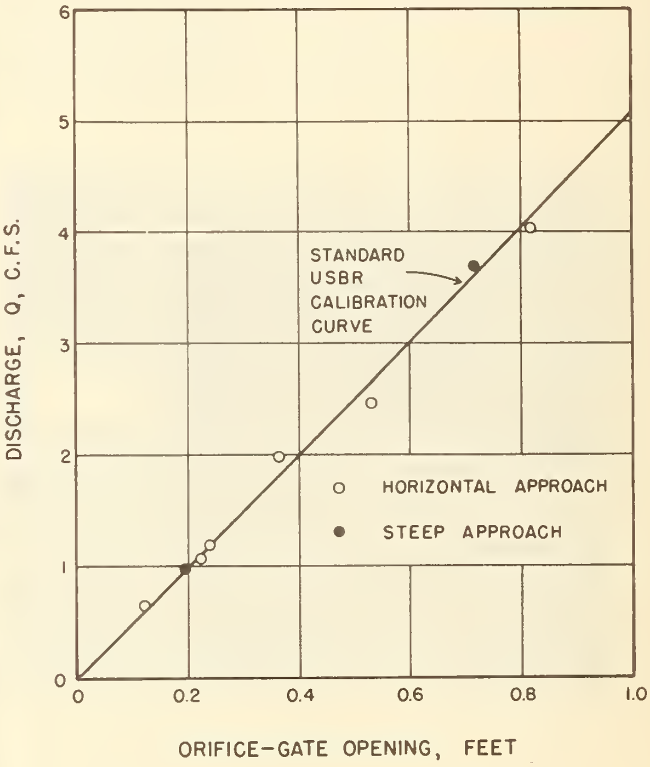

Figure 21.--Calibration curve for constant-head-orifice turnout with sediment deposits in the upstream approach, indoor tests.

Differential Head Readings

Fluctuations of the water surface at the staff gages can result in errors of several hundredths of a foot in the head readings. The magnitude of error likely to occur for different discharge conditions was determined by comparing staff readings with the differential head readings from piezometers connected to stilling wells for the indoor tests. Different observers read the differential head for five runs, with discharges varying from 2 to 5 cubic feet per second. The maximum variation in readings was 0.018 foot in 0.203 foot, a difference of 8.9 percent. An error in differential head of this magnitude would cause an error in the discharge measurement of 4.5 percent. The average error for 15 readings was 5.7 percent. This corresponds to an average error in discharge of less than 3 percent.

In the outdoor tests it was noted that staff gage readings at higher discharges were definitely in error. Figures 22 and 23 show the relationship between differential head read

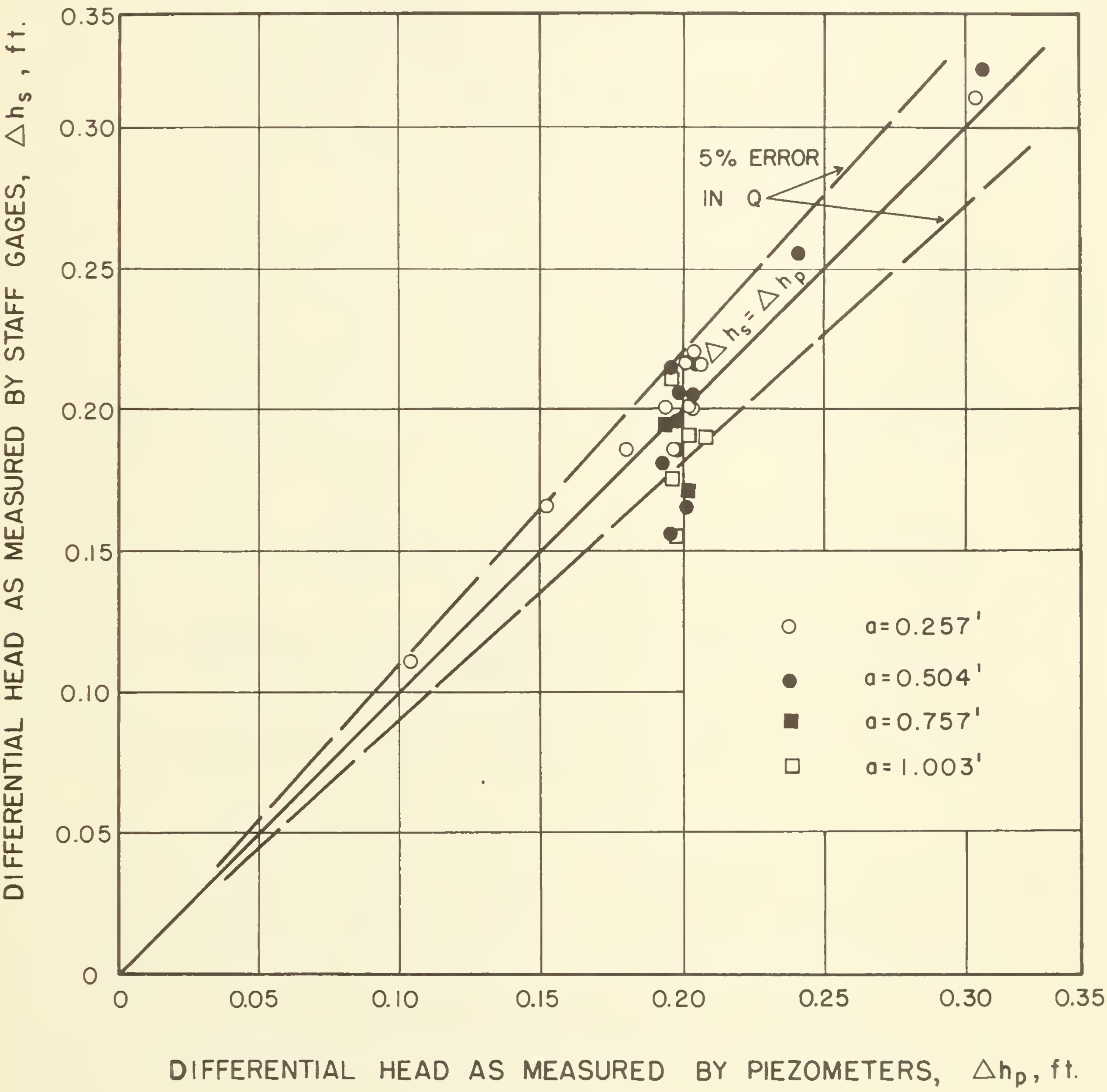

Figure 22.--Comparison of $\Delta \underline{h}$ as measured by staff gages and piezometers with stilling wells, for constant-head-orifice turnout with horizontal approach.

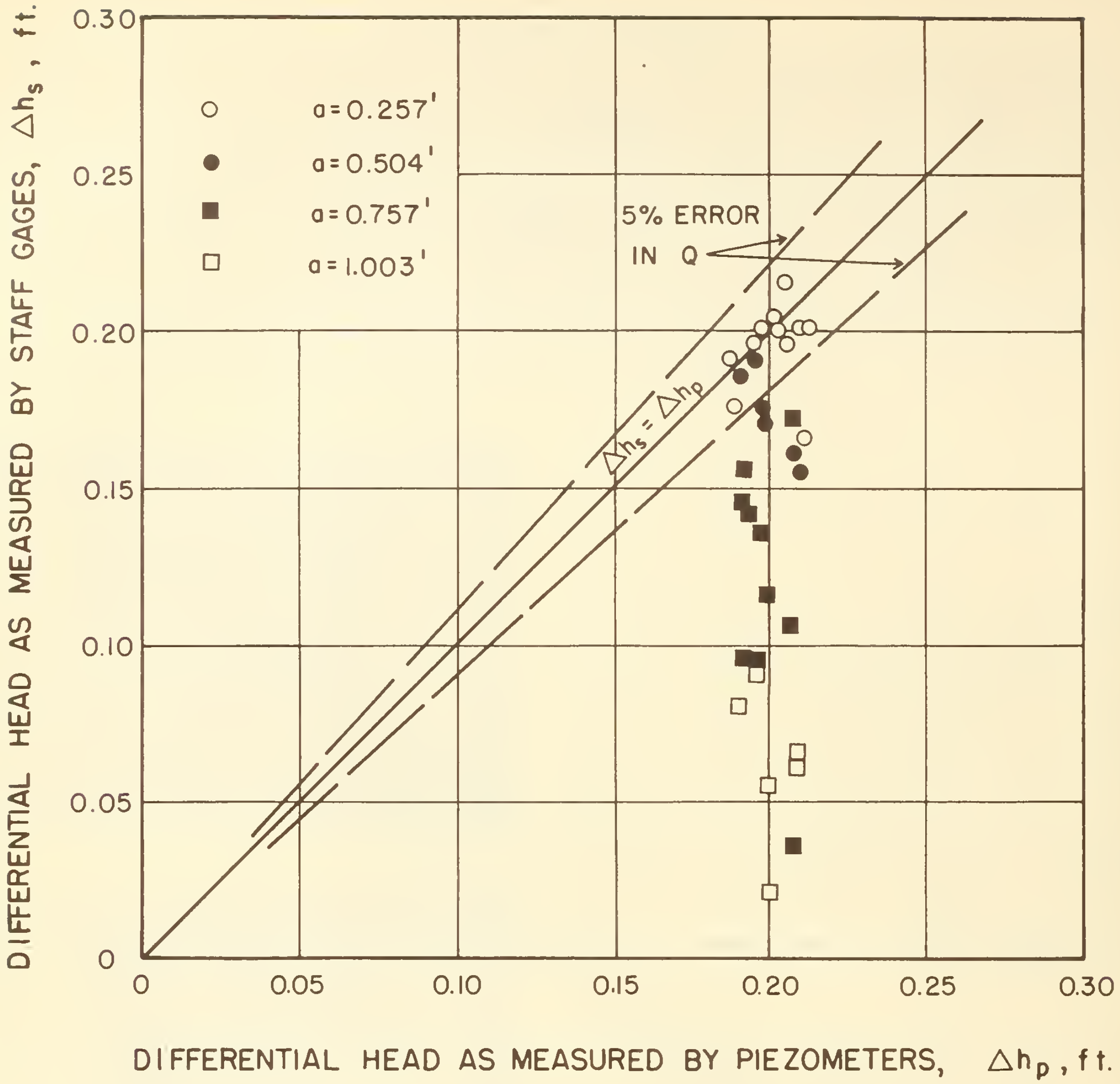

Figure 23.--Comparison of $\Delta \underline{h}$ as measured by staff gages and piezometers with stilling wells, for constant-head-orifice turnout with steeply sloping approach.

from the staff gages with that indicated by the piezometers, for both the horizontal and steep approach to the CHO. The dashed lines indicate variations in reading that could exist and still give less than 5-percent error in the indicated discharge. Staff gage readings are quite accurate for orifice-gate openings of less than one-half foot. For some of the larger orifice-gate openings the staff gages showed negative values of differential head when the piezometer indicated the standard 0.20 foot. It is apparent that extreme care should be taken in reading the staff gages for wider gate openings and that some sort of stilling device should be provided for the water surface at these gages; otherwise, piezometers and stilling wells should be provided for the structure. The differential head measured with the staff gages varied most from the true value when the upstream water surface was below the level specified on the design drawings. However, even when the depth of flow was that specified, the staff gage readings often indicated discharges more than 5 percent in error.

Canal Velocities

The arrangement of the outdoor test channel allowed the velocity of flow in the canal past the CHO entrance (canal velocity) to be varied by adjusting the tail gate. For the CHO with the horizontal approach, as the tail gate was opened, canal depth decreased while canal velocity increased. Because depths in the canals for this CHO were already lower than specified on the design drawings, the effects of velocity variation were inseparable from the effects of low upstream water levels. However, for the CHO with the steep approach, the depth of water in the canal could be kept constant as velocity was varied. Figure 24

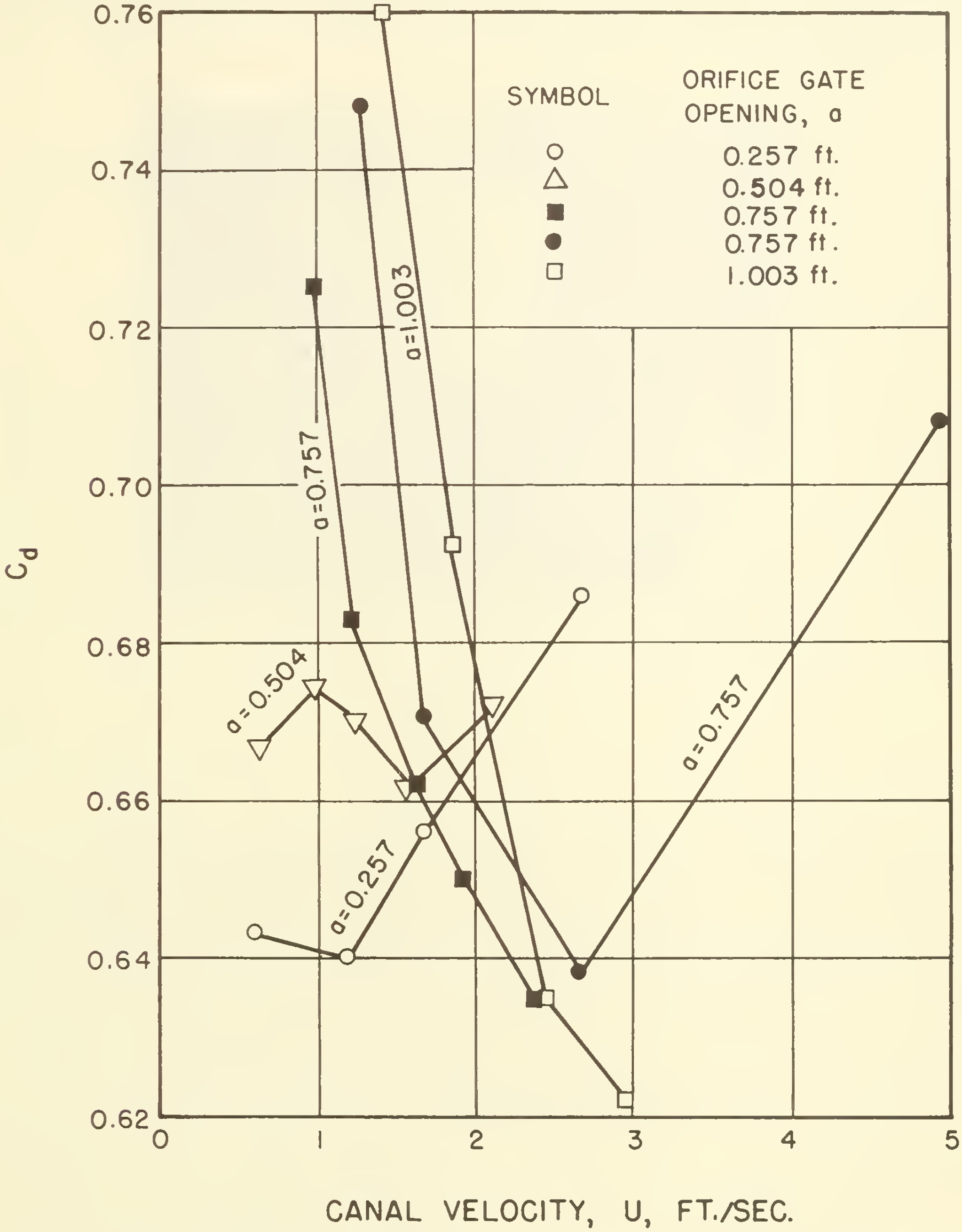

Figure 24.--Effect of canal velocity on discharge coefficient for constant-head-orifice turnout with steeply sloping approach, outdoor tests.

shows the variation of discharge coefficient with canal velocity, U, for the steep approach condition. Each curve in figure 24 represents a constant value of gate opening, a, as well as water depth, d. For small gate openings, C_d increases with increasing canal velocity. At larger gate openings, the discharge coefficient decreases with increasing canal velocity. An increase in canal velocity tends to strengthen the eddy formed in the approach section of the CHO (fig. 25). This eddy may reduce the effective area of the orifice opening and thus account for the computed reduction in the discharge coefficient at the large gate openings. The discharge coefficients deviate as much as 12 percent about the mean values at the larger gate openings. This deviation is the cause of the scatter of points about the calibration curve in figure 10. Users of the CHO should be aware of the inaccuracy of the CHO for large orifice-gate openings.

Figure 25.--Eddy formation, at high discharges, in the approach to the constant-head-orifice turnout.

Tail Water Variations

One of the purposes of the outdoor studies was to determine the effect of variations in tail water depth on the discharge through the CHO after the gate openings and Δh had been adjusted. In each test, canal depth and canal velocity were set. The orifice gate was opened to the desired height and the turnout gate was adjusted to produce the 0.20-foot differential head on the orifice gate. Discharge through the structure at this setting was measured. Then another gate immediately downstream of the turnout gate was lowered to increase tail water depth on the CHO. After the flow had stabilized, the discharge was again read without the position of either the orifice or the turnout gate being changed. This procedure was repeated to give data for two or three increments of change in tail water depth.

Discharge was reduced up to 40 percent from the initial flow conditions by increased tail water levels, (fig. 26). The discharge reduction was a result of the decreased differential head on the orifice gate caused by the increased tail water level. As the depth of tail water was increased, the canal depth upstream from the CHO was also increased to a small extent, thus producing a smaller change in the Δh across the orifice gate than would occur in the field. Changes in the discharge due to tail water variations would therefore be expected to reach even greater magnitude under field conditions, where canal depths would remain more nearly constant.

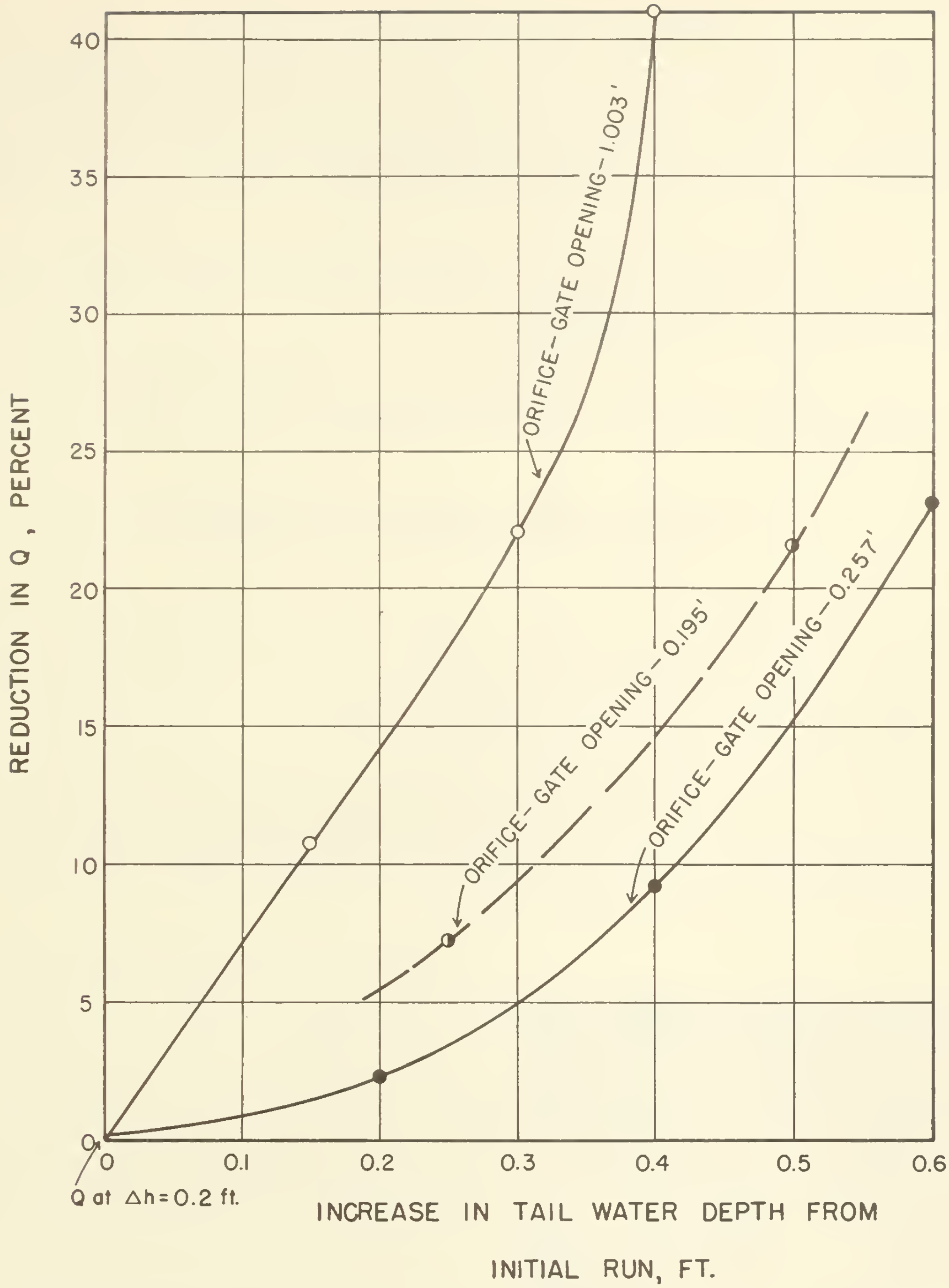

Figure 26.--Reduction in discharge resulting from increasing tail water depth after gate openings have been set for a $\Delta \underline{h}$ equal to 0.20 foot--steeply sloping approach, outdoor tests.

In a field installation, if the CHO is set at approximately the same grade as the lateral ditch being filled, the CHO may not be submerged when the gates are first opened. However, when the lateral becomes full, submergence of the CHO will result and the tail water depth will increase. Therefore, the person establishing the discharge in the CHO may need to make adjustments in the setting until flow conditions in the lateral ditch become stable.

Operation Under Other Differential Heads

One of the factors contributing to inaccuracy of measurement by the CHO is the small differential head under which it operates. Errors of the order of 0.01 foot in reading the staff gages can cause significant errors in the calculated discharge. For instance, errors of 0.01 foot on each staff gage can cause a cumulative error of 0.02 foot or 10 percent in $\Delta \underline{h}$. This is equivalent to a 5-percent error in discharge. If the device could be operated under larger head differentials, this type of error would be reduced.

The use of a constant $\Delta \underline{h}$ larger than 0.20 foot would have disadvantages, also. For a larger $\Delta \underline{h}$, the velocity of flow through the orifice gate would be greater than for the $\Delta \underline{h}$ now used. Larger flow disturbances would occur in the basin between the two gates than those that exist under present operating conditions.

Also, it is desirable to keep head losses as low as possible in all parts of an irrigation water distribution system so that the maximum amount of land can be served by the system.

A CONSTANT-HEAD-ORIFICE FARM TURNOUT CONSTRUCTED OF STEEL PANELS

The U.S. Steel Corporation[5] currently manufactures a variety of modular, galvanized sheet steel sections that can be bolted together to form small control structures for irrigation water. The sections include gates and gate frames to be placed in the structures. A study was undertaken to determine whether or not these gate frames might be suitable for use in measuring irrigation water as well as in controlling it. A constant-head-orifice turnout was constructed from the steel sections and rated in the outdoor test channel. Two 24-inch x 24-inch gates were used for orifice and turnout gates in the structure. The orifice gate was set back 42 inches from the junction of the canal bed and side wall. The turnout gate was placed another 36 inches downstream from the orifice gate. Three configurations were tested: (1) with the floor of the CHO flush with the canal bed; (2) with the floor 6 inches below the canal bed; and (3) with the floor 12 inches below the canal bed. A CHO constructed from the steel panels is shown in figure 27.

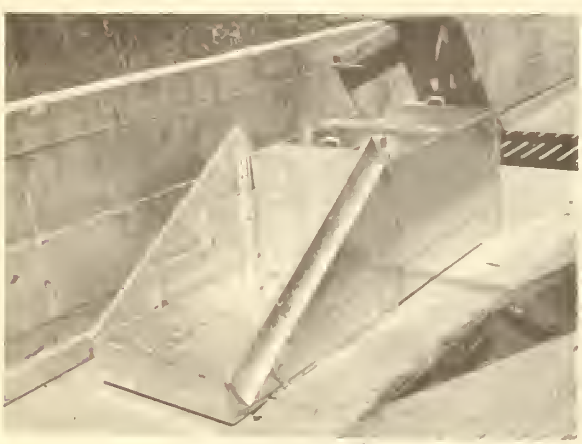

Figure 27.--Constant-head-orifice farm turnout constructed from steel panels.

Gate frames for these structures are constructed so that the gate may be placed on either side of the frame. The gates have a flange or lip on one side of the lower edge and have spring clips on the other side to keep the gate from slipping in the frame. The results of these studies are all for the case of the gate in the standard position--with the lower lip facing upstream and the spring clips on the downstream side of the gate frame. Differential head data were taken at both the right and left walls (looking downstream into the CHO) of the turnout structure. The data contained in this evaluation of the steel-panel CHO correspond to readings of differential head taken at the left wall.

The calibration curves obtained for each of the three geometries of the CHO were nearly identical and are shown in figure 28. The solid

[5] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

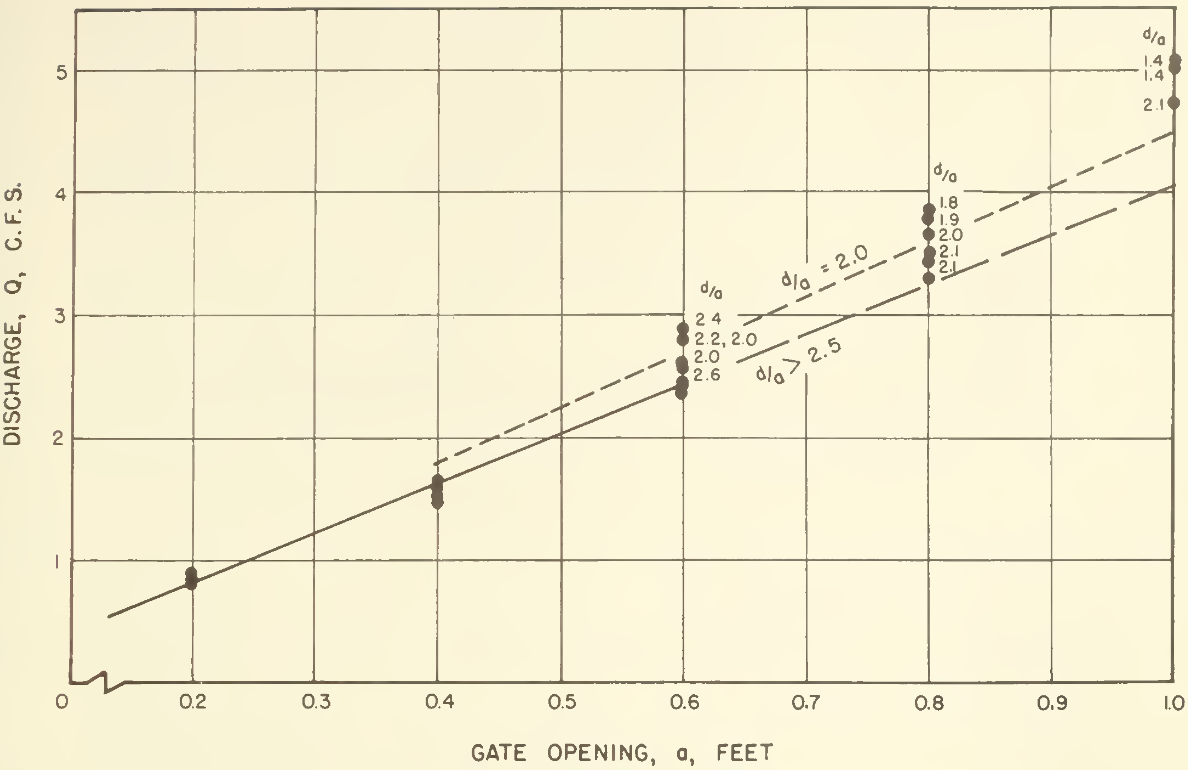

Figure 28.--Calibration curve for constant-head-orifice turnout constructed with steel panels.

section of the rating curve, included between values for a of 0 and 0.6 foot, represents nearly constant values of the discharge coefficient. For values of a larger than 0.6 foot, the discharge coefficient increased. The heavy dashed line in figure 28 represents the calibration curve for the CHO for orifice-gate openings greater than 0.6 foot, assuming that the discharge coefficient will remain constant. (The conditions for constant discharge coefficient are discussed in the following paragraph.) The individual data points in figure 28 plot above the dashed line, indicating that discharge coefficients are higher for the larger gate openings. The calibration for d/a values of 2.0 is indicated by the upper line (short dashes).

The effect of flow pattern geometry on discharge coefficient is shown in figure 29, where discharge coefficient is plotted as a function of the ratio d/a, where d is the flow depth of water immediately upstream from the gate and a is the height of the orifice-gate opening. For values of d/a greater than 2.5, the discharge coefficient is nearly constant although there is some scatter about the mean value. As the d/a ratio drops below 3.0, values of the discharge coefficient increase. This curve can be used in conjunction with the discharge equation, $Q = C_d A \sqrt{2g\Delta h}$ to estimate discharge when d/a is less than 2.5.

Because of the turbulent flow conditions, it was often difficult to take accurate readings of the differential head by using the staff gages. In figure 30, the values of Δh obtained by staff gage readings and by piezometers in the steel-panel CHO are compared. The value of Δh by the staff gages tends to be lower than that read by means of the piezometers, especially for the larger orifice-gate openings. The dashed line in figure 30 represents the point at which the staff gage reading would give errors of 10 percent. An error of 10 percent in Δh corresponds to a 5-percent error in the measured discharge. It can be seen that errors of this magnitude were made for some runs at all gate openings. It would therefore appear that if accurate measurements are to be obtained from the steel panel CHO, either the Δh should be determined from the piezometers or some kind of effective stilling device should be installed around the staff gages.

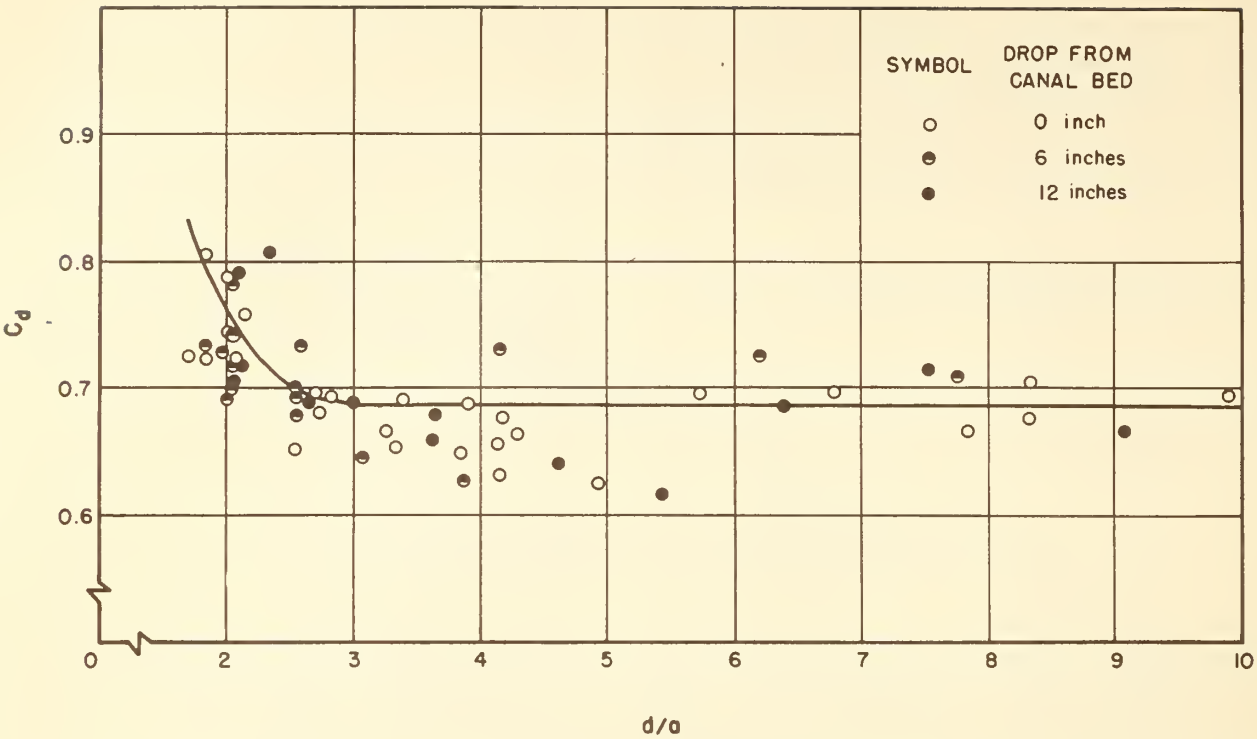

Figure 29.--Variation of discharge coefficient with flow pattern geometry for constant-head-orifice turnout constructed with steel panels.

Before the results of this study are applied to any particular structure, the orifice-gate opening should be measured exactly and the area of the opening as a function of the opening height should be determined. Then the discharge coefficients obtained from this study can be applied to determine the discharge. Discharges through gates of other sizes can also be estimated by using the discharge coefficients from this study (U.S. Steel Corp. furnishes these gates in 12-, 18-, 24-, 30-, and 36-inch widths). It has been shown in other studies of the constant-head-orifice turnout that discharge coefficients obtained from large scale models apply also to prototype structures that are geometrically similar.

Suggestions.--The optimum elevation of the orifice-gate frame relative to the elevation of the canal bed is determined by the normal depth of flow in the canal. For canal depths approaching 2 feet, the floor of the turnout structure can be placed level with the canal bed. The values of d/a will still be greater than 2.5 for all except the largest gate openings. The

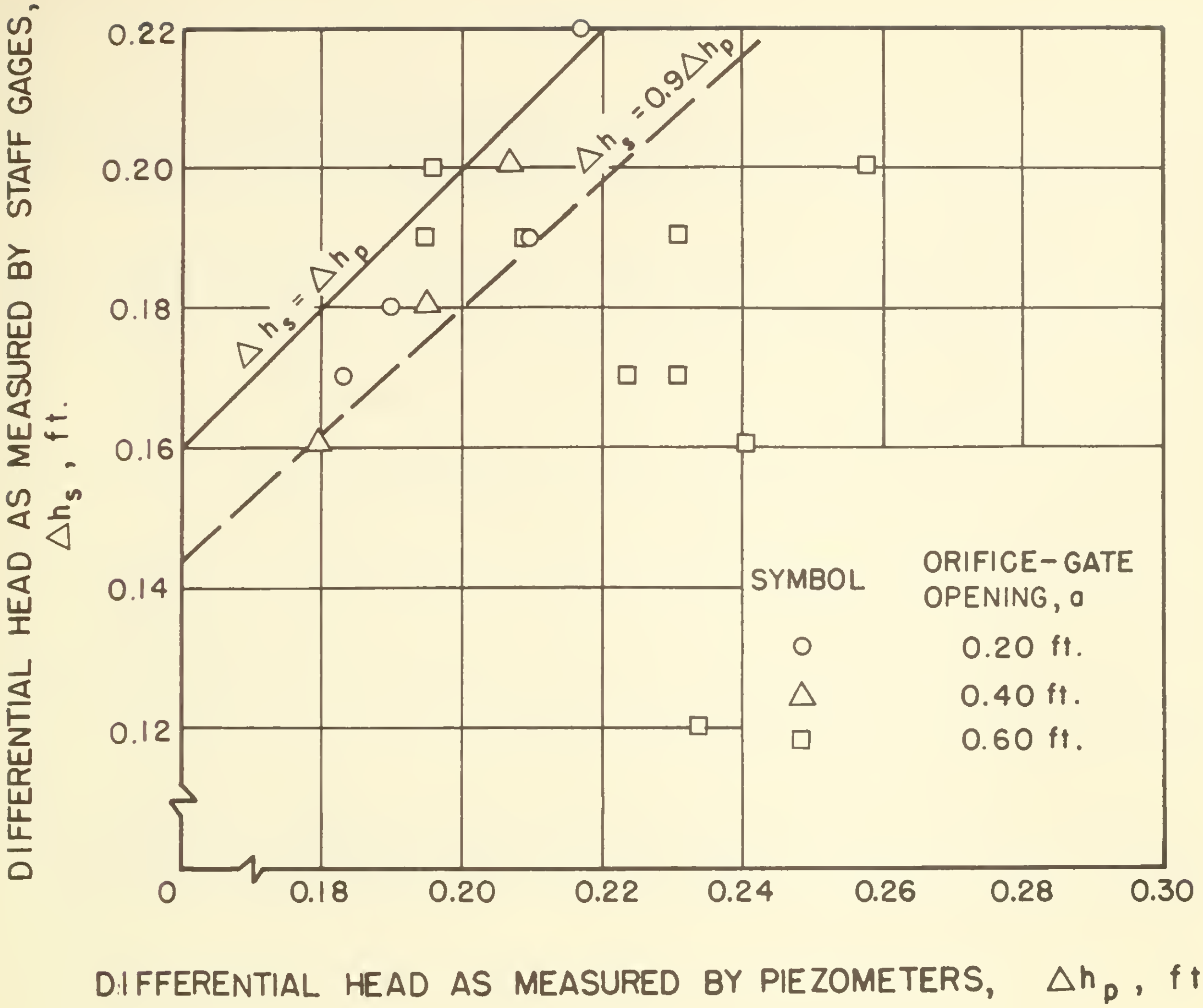

Figure 30.--Comparison of $\Delta \underline{h}$ as measured by staff gages and piezometers with stilling wells, steel panel CHO.

discharge coefficient increases rapidly as values for $\underline{d}/\underline{a}$ go below 2.5. Limitations of the experimental equipment did not allow determination of $\underline{C}_d$ values for small $\underline{d}/\underline{a}$ values. It is recommended that the CHO not be used for flow measurement for $\underline{d}/\underline{a}$ values less than 2.0. For canal depths of about 1.5 feet, the floor of the CHO should be dropped 6 inches below the level of the canal bed. For lower water levels, a drop of 12 inches into the turnout structure is advisable.

Staff gages within the structure provide rather poor indications of the true differential head on the orifice gate. If at all possible, head readings should be made in stilling wells. Piezometers, about 1/4 inch in diameter, should be placed flush with the inside wall of the turnout and connected to the stilling wells with tubing. The piezometers should be located 8 inches upstream and downstream of the gate frame and about 1.2 feet above the floor of the turnout but below the lowest anticipated water surface. For existing structures, small stilling devices that fit around the staff gages will improve the accuracy of measurement.

CONCLUSIONS

The calibration of the constant-head-orifice turnouts studied, constructed with several different geometries and operated under several flow conditions, did not vary greatly from the calibration of similar structures reported by the USBR. Under most conditions these constant-head-orifice turnouts will provide accurate measurement and regulation of irrigation water discharges.

A CHO constructed of steel modular panels also served as a suitable water measurement device. The accuracy of measurement was not as good as with the USBR gates. Also, the steel structures now available cannot be adapted to as wide a range of canal depths as the USBR structures.

Weeds or other obstructions in the orifice gate opening caused reductions in discharge of 40 percent or more.

Sediment diverted into the turnout was not deposited near the orifice gate. Therefore, sediment deposits had no significant effect on the calibration of the orifice.

High velocities of flow in the canal past the entrance to the turnout did not cause consistent effects on the calibration for the smaller gate openings. For large orifice-gate openings, increasing canal velocity caused a decrease in the discharge coefficient.

An increase in tail water elevation, after the openings of the gates and the differential head had been set, caused a significant decrease in the discharge. Therefore, when the constant-head-orifice turnout is operated, all gate adjustments should be checked after the upstream and downstream water levels have become stable.

The coefficient of discharge was nearly constant when the ratio of the water depth immediately upstream from the orifice gate (d) to the height of the gate opening (a) was greater than 4.0. For smaller ratios the discharge coefficient increased rapidly. The turnout structures should therefore be installed so that the water depth will be adequate to provide a nearly constant discharge coefficient.

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